Strategies to Observe First Light with JWST

Rogier Windhorst (ASU) — JWST Interdisciplinary Scientist

S. Cohen, R. Jansen (ASU), C. Conselice (UK), S. Driver, S. Wyithe (OZ), B. Frye (UofA), & H. Yan (U-MO)

+ ASU Grads: N. Hathi, H. Kim, M. Mechtley, R. Ryan, M. Rutkowski, B. Smith, & A. Straughn

Outline:

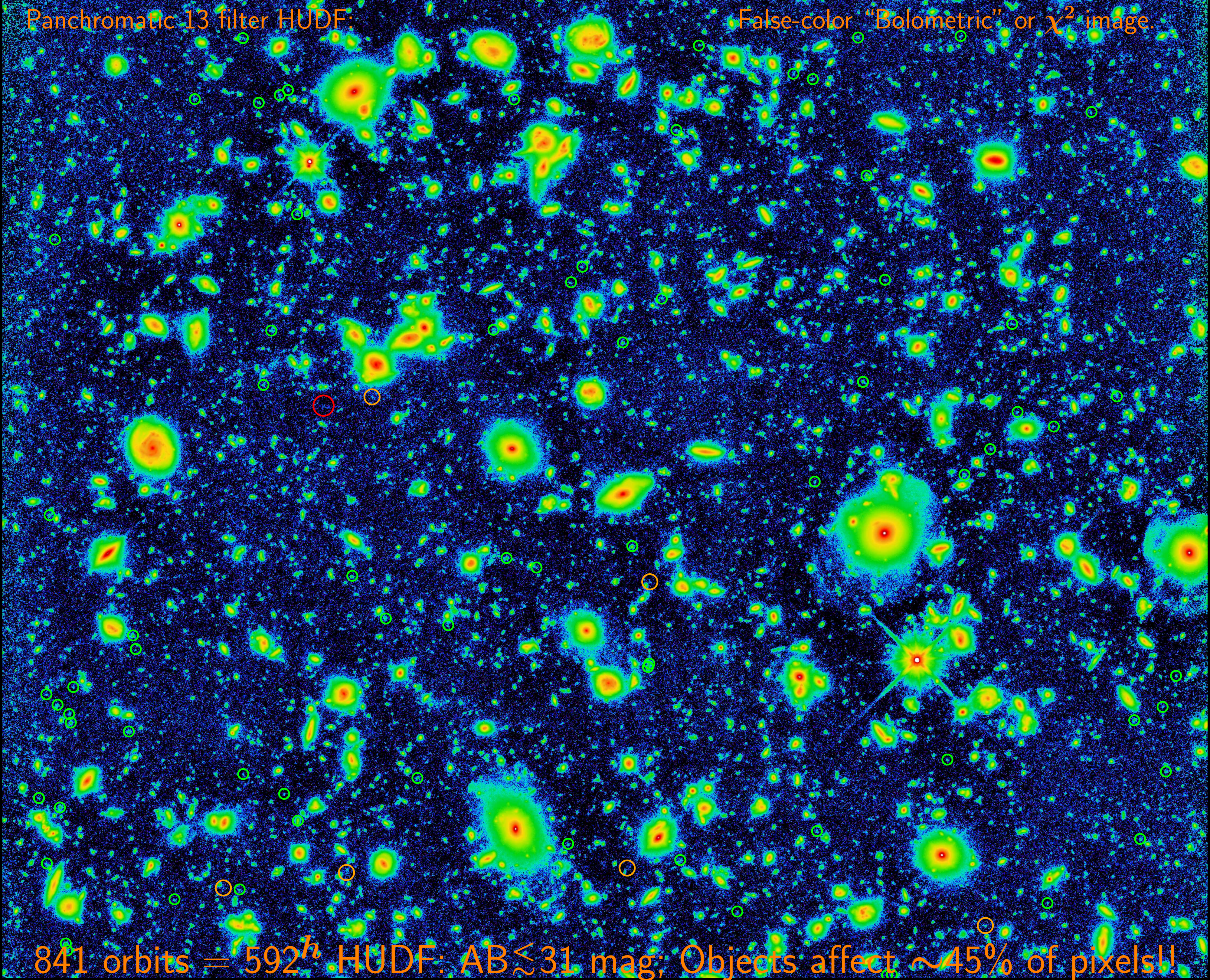
(1) Strategies to Observe First Light with JWST:

- How many random fields compared to the best lensing targets?

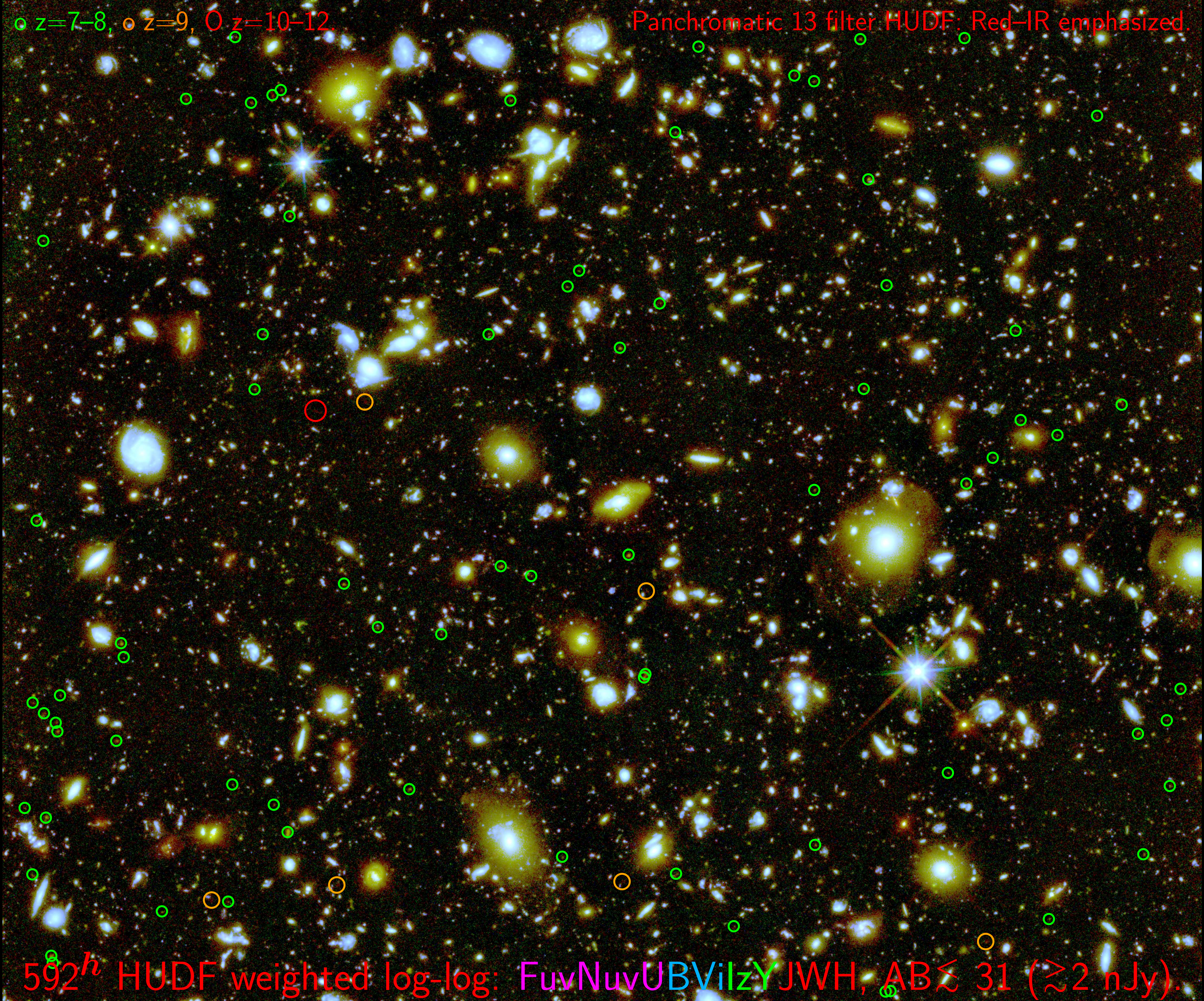
(2) Summary and Conclusions.

Talks at the JWST GTO Workshop, Aug. 7–8, STScI, Baltimore (MD). All 3 talks are on:

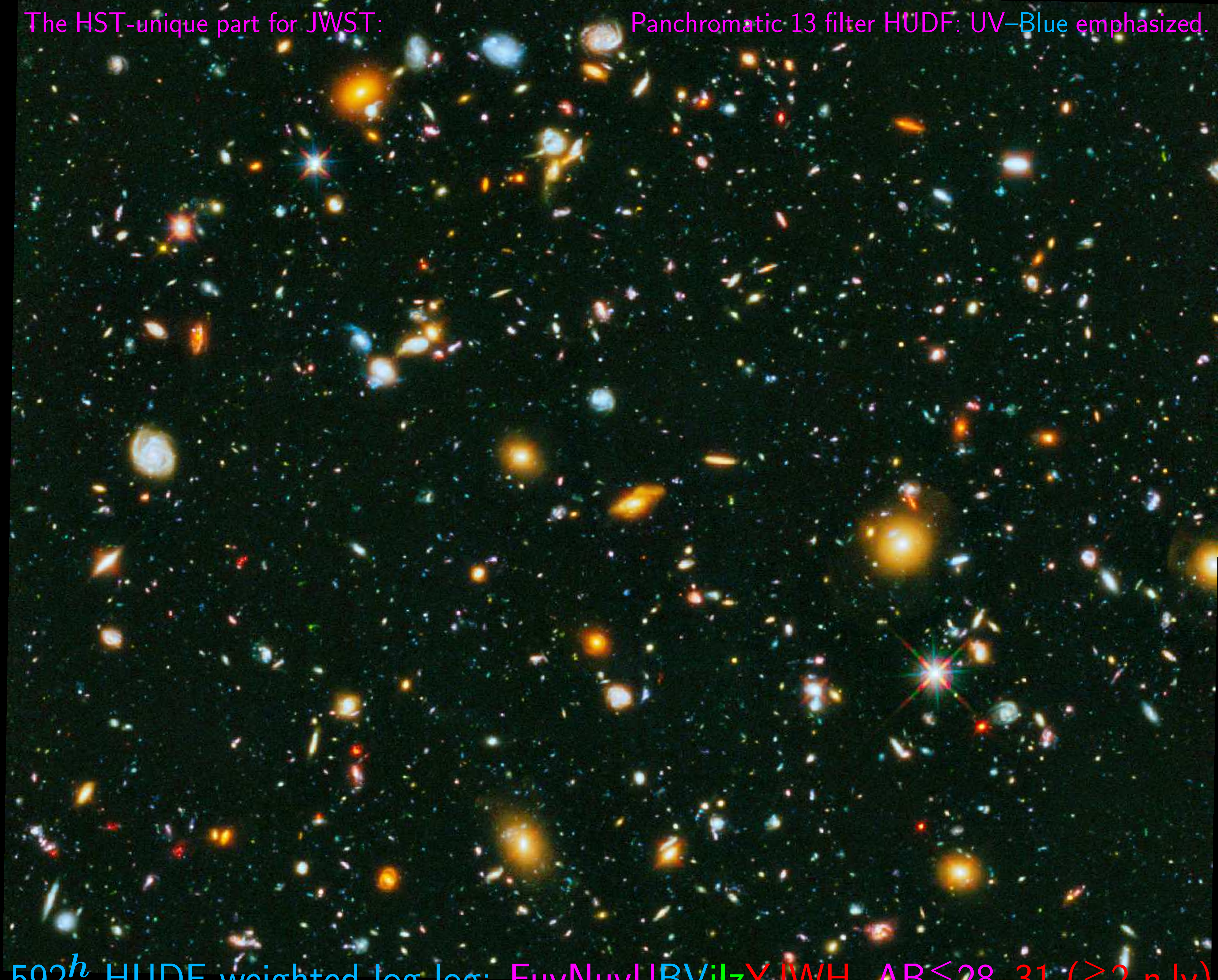
`http://www.asu.edu/clas/hst/www/jwst/jwsttalks/windhorst14_firstlight_AGNhosts.pdf`



Panchromatic 13 filter HUDF:
False-color "Bolometric" or χ^2 image.
841 orbits = 592^h HUDF: AB$\lesssim$31 mag; Objects affect $\sim$45% of pixels!!

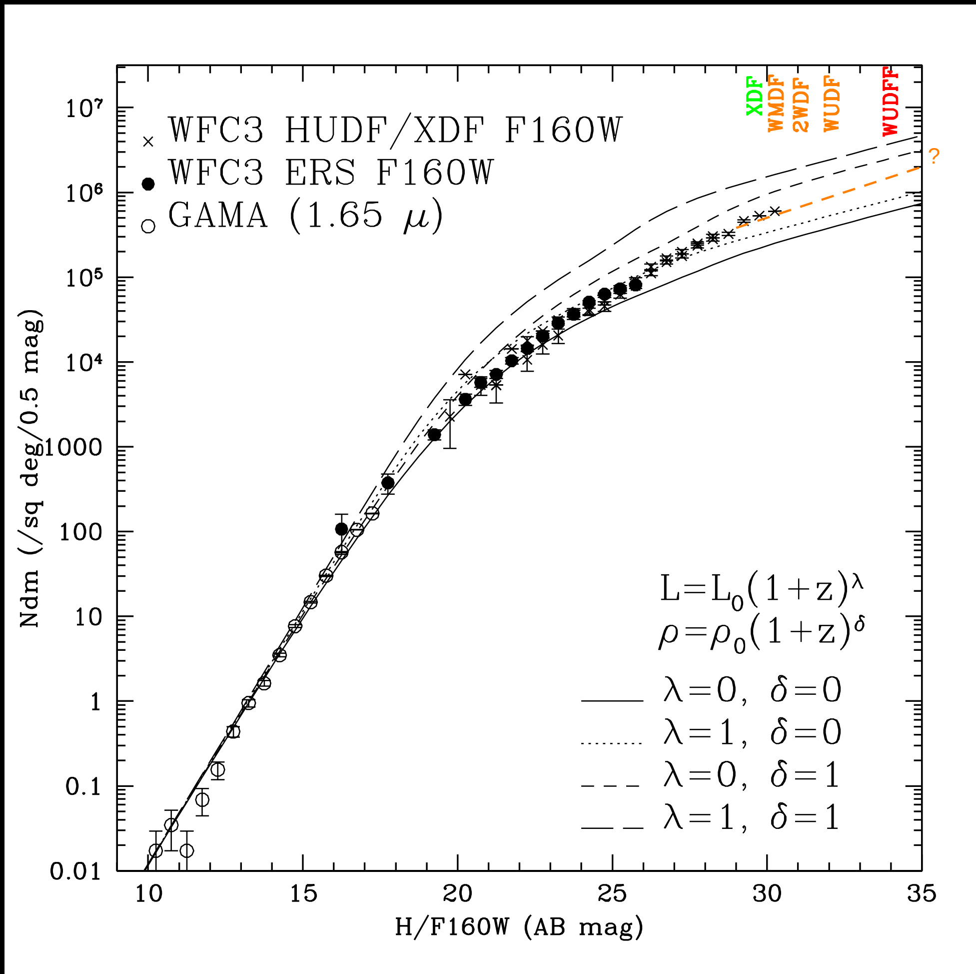

o z=7–8, o z=9, O z=10–12.
Panchromatic 13 filter HUDF: Red–IR emphasized.
592^h HUDF weighted log-log: FuvNuvUBViIzYJWH, AB$\lesssim$ 31 ($\gtrsim$2 nJy).

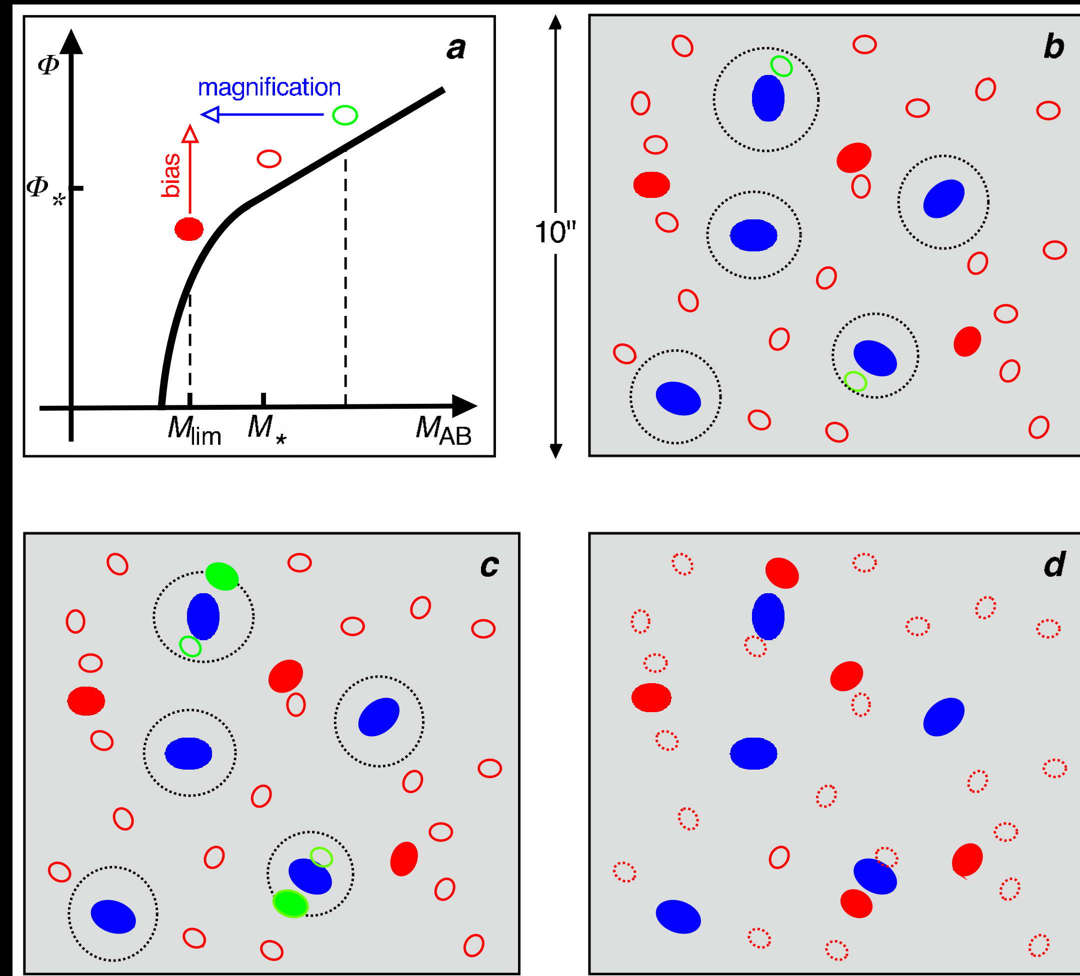
The HST-unique part for JWST: Panchromatic 13 filter HUDF: UV–Blue emphasized.



592^h HUDF weighted log-log: FuvNuvUBViIzYJWH, AB$\lesssim$28–31 ($\gtrsim$2 nJy).

HUDF WFC3 IR Galaxy Counts: What to expect in its (Ultra)Deep Fields?



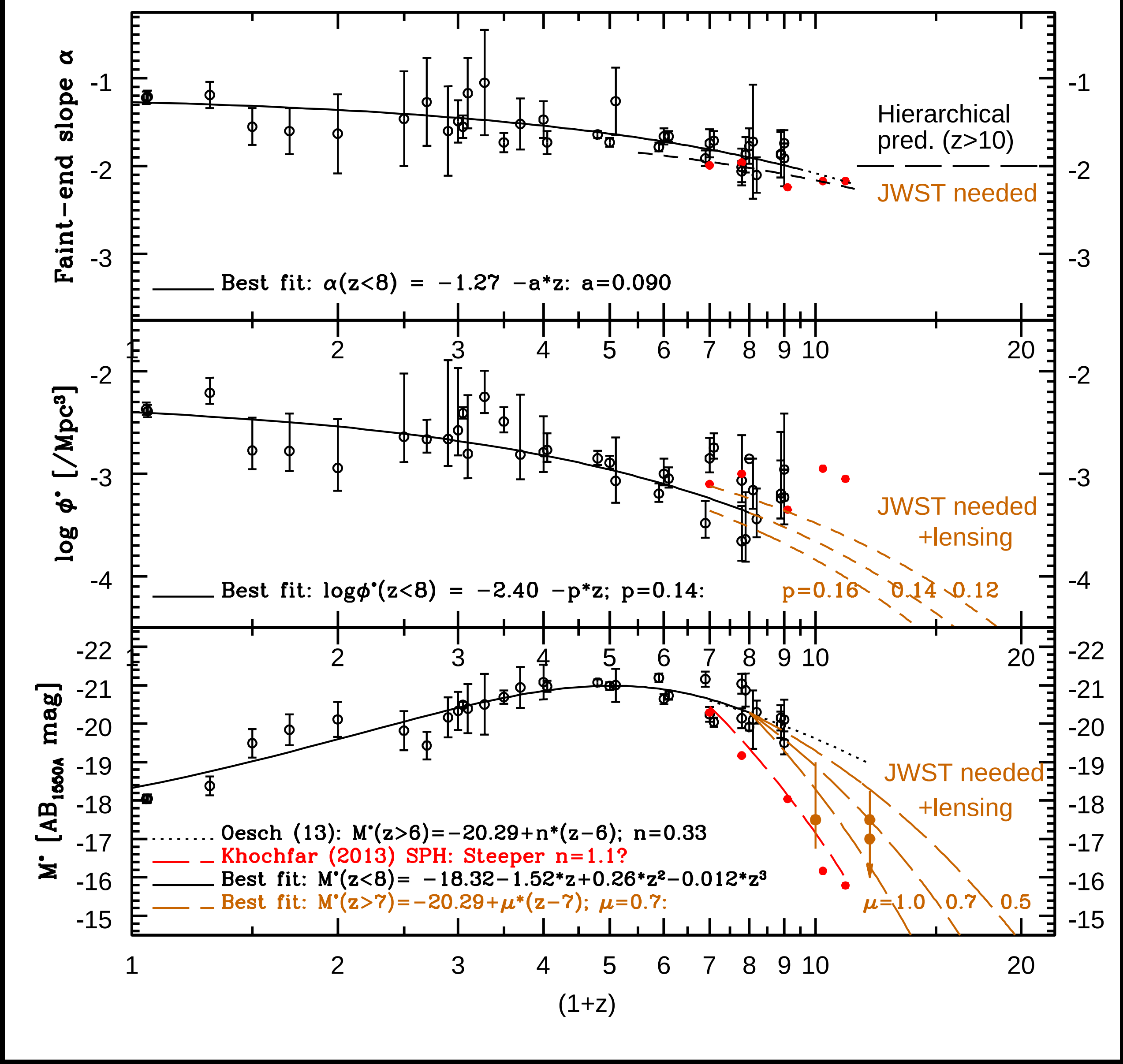


1.6μm counts (Windhorst+2011). [F150W, F225W, F275W, F336W, F435W, F606W, F775W, F850LP, F105W, F125W, F140W not shown].

- Faint-end near-IR count-slope≃0.12±0.02 dex/mag ⟺

Faint-end LF-slope(z_{med} ≃1.6) α≃–1.4 ⇒ reach M$_{AB}$≃–14 mag.

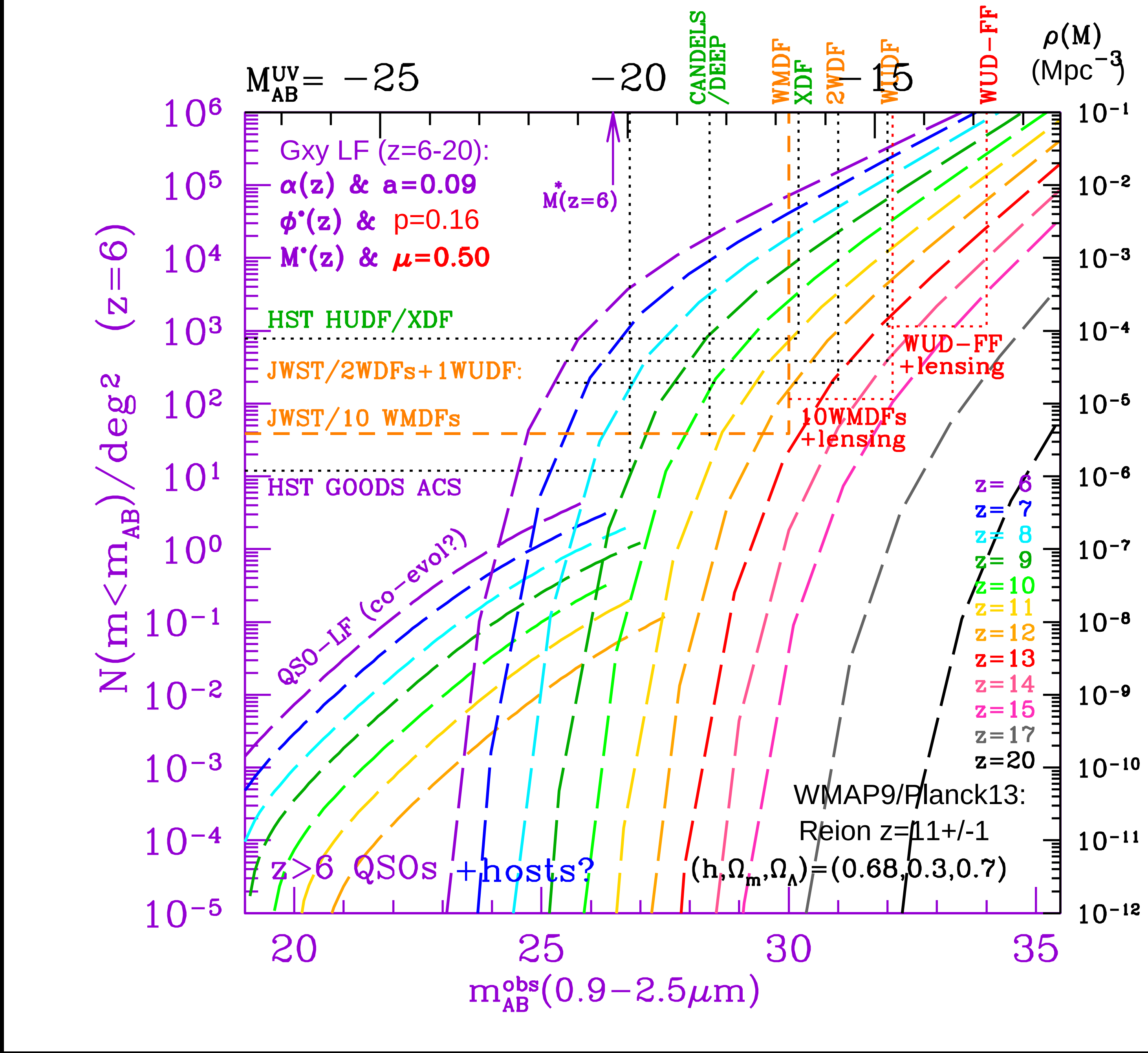
- WUDF (- - -) can see AB≲32 objects: M_{AB} ≃–15 (LMCs) at z≃11.
- Lensing may change the landscape for JWST observing strategies (WUDFF).



Evolution of Schechter UV-LF: faint-end LF-slope α(z), Φ^* (z) & M^* (z):

- For JWST z$\gtrsim$8, expect $\alpha\lesssim$–2.0; $\Phi^* \lesssim 10^{-3}$ (Mpc^{-3}) (Oesch$^+$ 11).
- HUDF: Characteristic M^* may drop below –18 or –17.5 mag at z$\gtrsim$10.

$\Rightarrow$ May have significant consequences for JWST survey strategy.

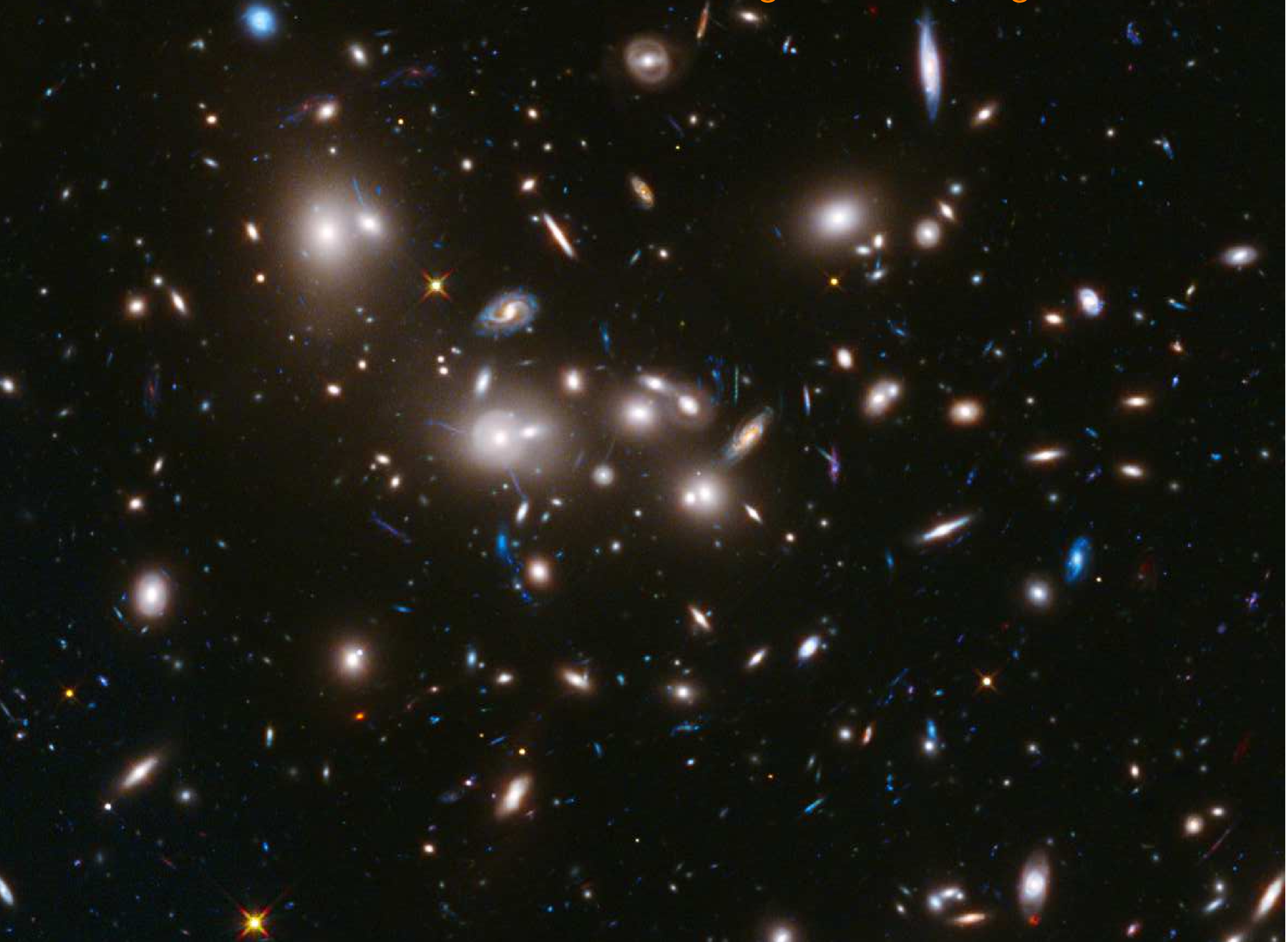


Schechter LF (z≲6≲20) with best-fit α(z), Φ^* (z), M^* (z) & μ=0.50.

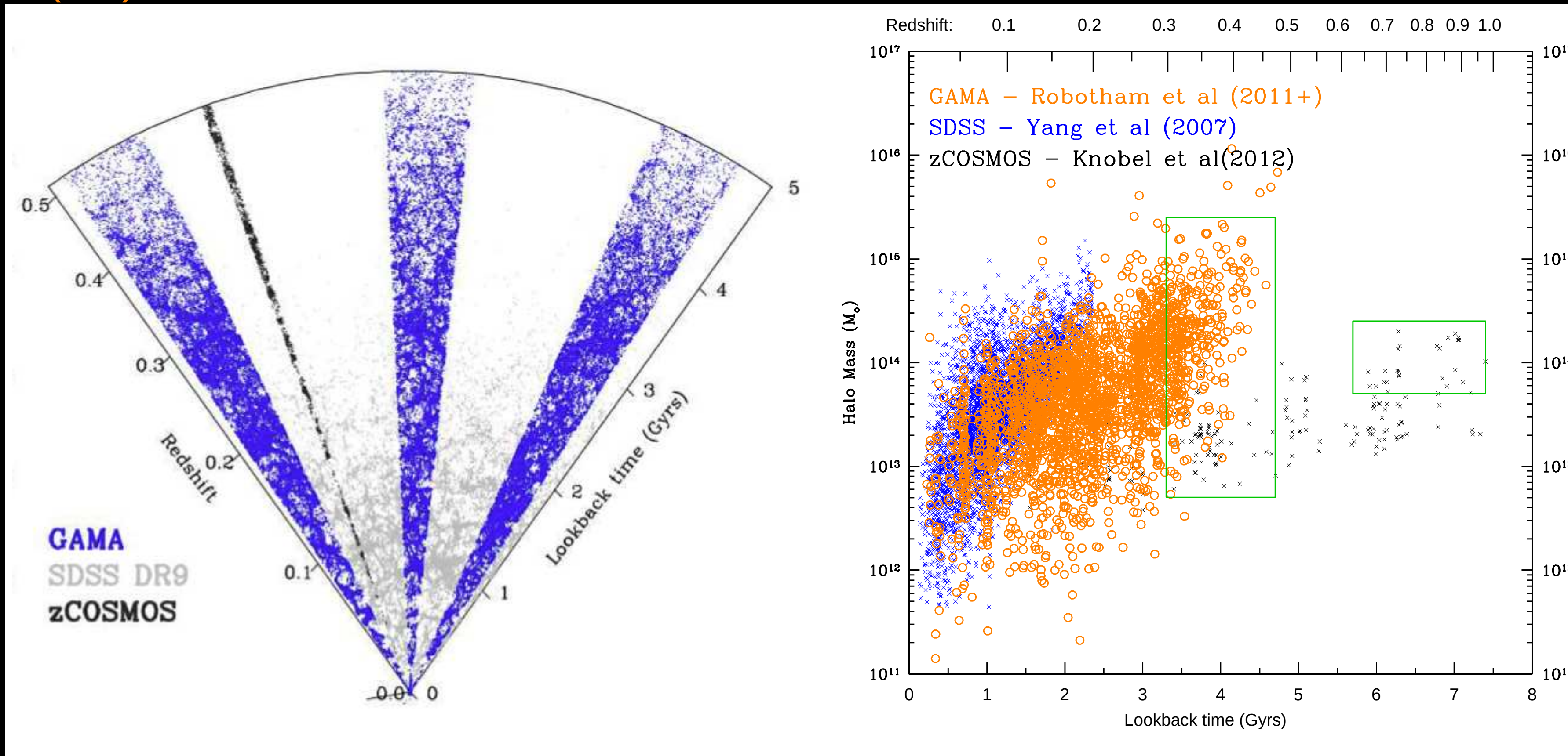
Area/Sensitivity for: HUDF/XDF, **10 WMDFs**, 2 WDFs, & 1 WUDF.

- May need lensing targets for WMDF–WUDFF to see z≃14–16 objects.

HST Frontier Field A2744: JWST needs lensing to see First Light at $z \gtrsim 11$–15.



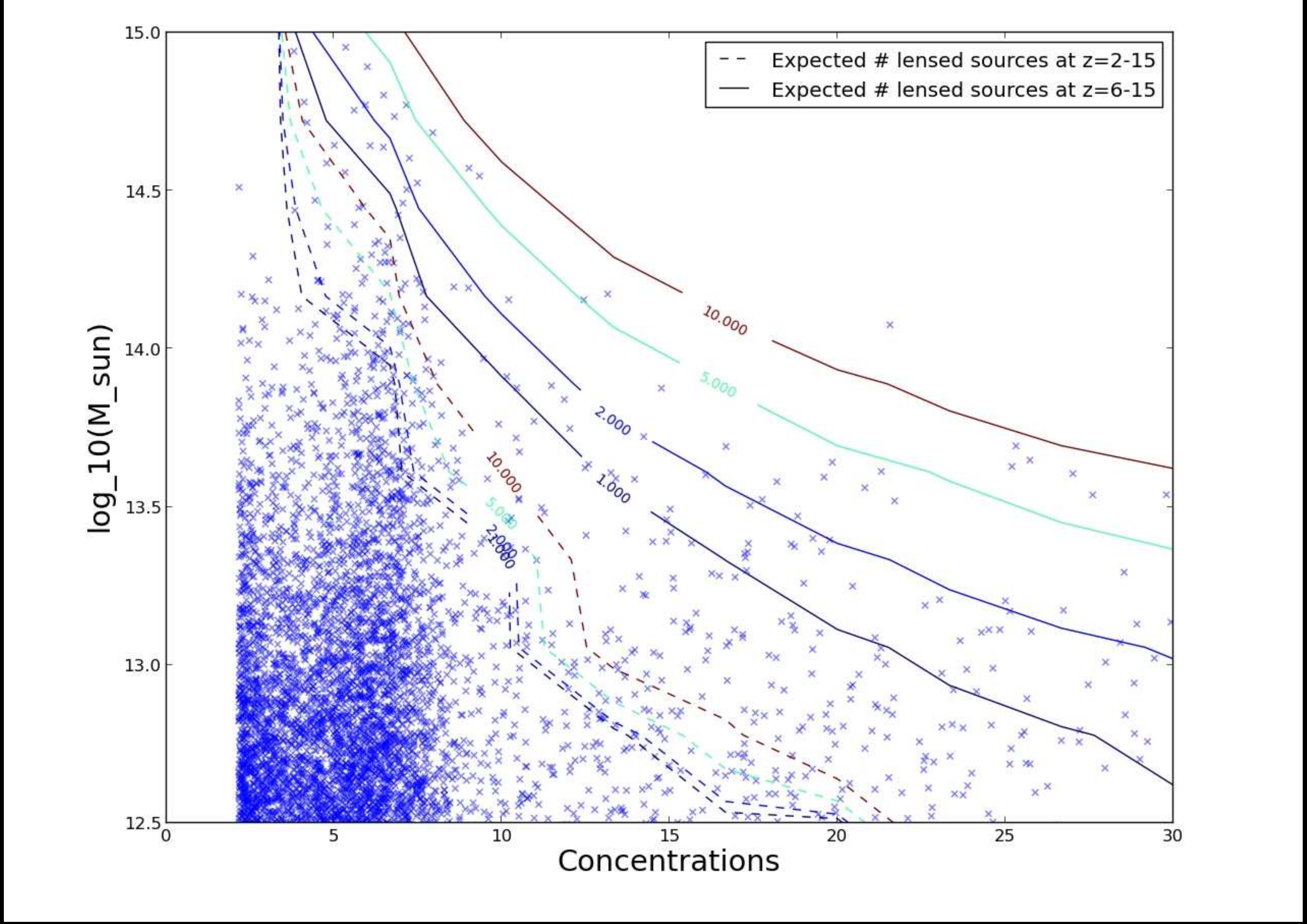
(3b) Gravitational Lensing to see First Light population at z$\gtrsim$10.



What are the best lenses in 2018: Rich clusters or (compact) galaxy groups?

[Left] Redshift surveys: SDSS z$\lesssim$0.25 (Yang$^+$ 2007), GAMA z$\lesssim$0.45 (Robotham$^+$ 2011), and zCOSMOS z$\lesssim$1.0 (Knobel$^+$ 2012).

- GAMA: 22,000 groups z$\lesssim$0.45; 2400 with $N_{spec}\gtrsim$5 (Robotham$^+$ 11).
  - $\lesssim$10% of GAMA groups compact for lensing (Konstantopoulos$^+$ 13).
- Large group sample to identify optimal lens-candidates for z$\gtrsim$6 sources.



GAMA group mass versus concentration assuming NFW DM halo profiles.
Contours = Nr of expected lensed sources (Δz=1; Barone-Nugent[+] 13).

- 10 WMDFs on best GAMA groups add ∼50–100 z≃6–15 sources (AB≲30).
- Also get ≳10× more (≳500) lensed sources at ≃2–15.

WUDFF if pointed at clusters adds ∼6× more (≳3000) sources at 6≲z≲15.

Conclusions re. JWST First Light Strategies

(1) JWST First Light studies will require an optimal mix of Medium-Deep, Deep and Ultradeep Fields:

• This IDS GTO team will do ∼10×7 hr Webb Medium-Deep Fields (10 WMDF's), anticipating that:

• The NIRCam team will likely do a Webb Deep (∼200 hr) WDF, and

• JWST GO's may at some point do an Webb Ultradeep Field (800 hr WUDF).

(2) Purpose of this Conference: Determine optimal combination of *random* Webb (Medium) Deep Fields, and fields targeting *the best lensing groups/clusters*.

• Lensing fields need to consider the brightness of — and low-level gradients in — IntraCluster Light (ICL) *and* low-level out-of-field (rogue-path) straylight.

SPARE CHARTS

- References and other sources of material shown:

http://www.asu.edu/clas/hst/www/jwst/ [Talk, Movie, Java-tool]

http://www.asu.edu/clas/hst/www/ahah/ [Hubble at Hyperspeed Java–tool]

http://www.asu.edu/clas/hst/www/jwst/clickonHUDF/ [Clickable HUDF map]

http://www.jwst.nasa.gov/ & http://www.stsci.edu/jwst/

http://ircamera.as.arizona.edu/nircam/

http://ircamera.as.arizona.edu/MIRI/

http://www.stsci.edu/jwst/instruments/nirspec/

http://www.stsci.edu/jwst/instruments/fgs

Gardner, J. P., et al. 2006, Space Science Reviews, 123, 485–606

Mather, J., & Stockman, H. 2000, Proc. SPIE Vol. 4013, 2

Windhorst, R., et al. 2008, Advances in Space Research, 41, 1965

Windhorst, R., et al., 2011, ApJS, 193, 27 (astro-ph/1005.2776).

Two fundamental limitations may determine ultimate JWST image depth:

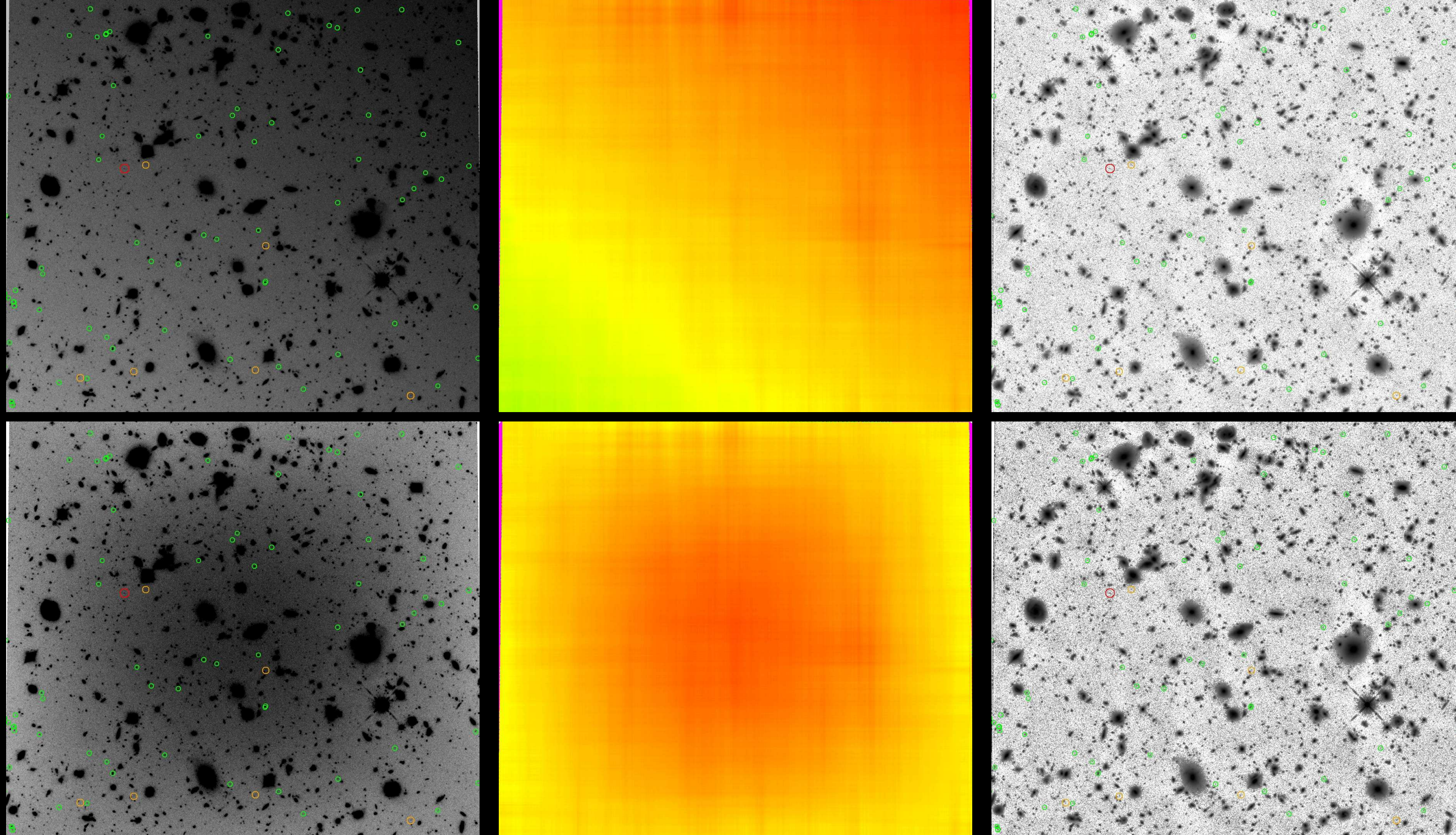
(1) Cannot-see-the-forest-for-the-trees effect [Natural Confusion limit]:

Background objects blend into foreground because of their own diameter
$\Rightarrow$ Need multi-λ deblending algorithms.

(2) House-of-mirrors effect ["Gravitational Confusion"]: Most First Light objects at $z \gtrsim 12$–14 may need to be found by cluster or group lensing.

$\Rightarrow$ Need multi-λ object-finder that works on sloped backgrounds.

$\Rightarrow$ If $M^*(z \gtrsim 10) \gtrsim -18$, need to use & model gravitational foreground.



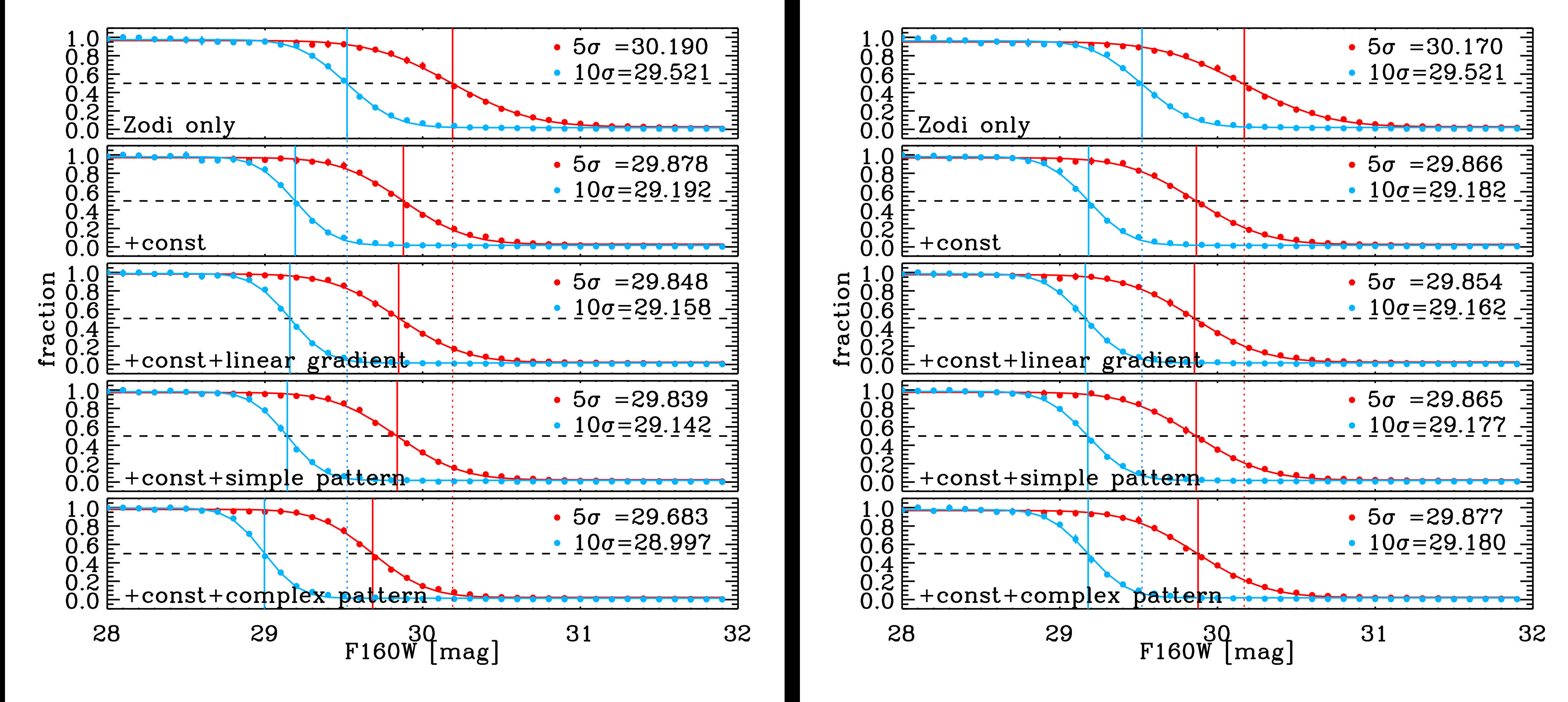
[TOP]: [Left] HUDF F160W image with worst case (95% of Zodi) rogue-path amplitude imposed + ±4% *linear gradient* from corner-to-corner.

[Middle]: Best fit to sky-background with R. Jansen's "rjbgfit.pro".

[Right]: HUDF image from left with best-fit sky-background subtracted.

[BOTTOM]: Same as top row, but with a *single-component simple 2D pattern* superimposed, modeled and removed, respectively.

• If JWST rogue-path straylight has slight or complex gradients, we must be careful when imaging lensing clusters with strong ICL!

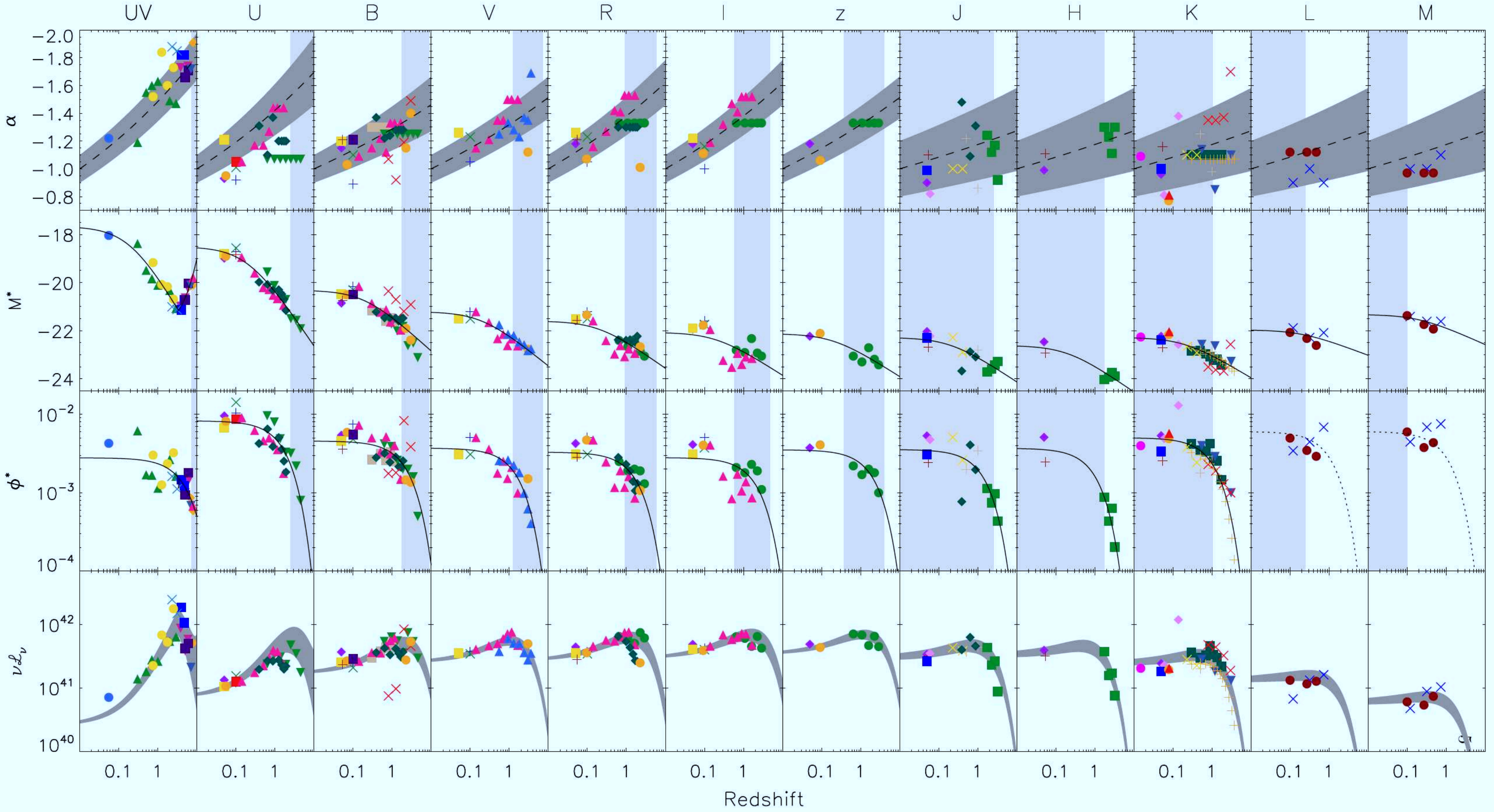


[LEFT]: Completeness tests in HUDF F160W image *before* imposing on top of Zodi (22.70 mag arcsec^{-2} ; Petro 2001) [2nd–5th row]: *Constant 95% of Zodi amplitude*; *+ a ±4% linear gradient*; or *simple 2D pattern of ±4%*; or *a more complex pattern.*

[RIGHT]: Same as left *after* best fit to + removal of image sky-background.

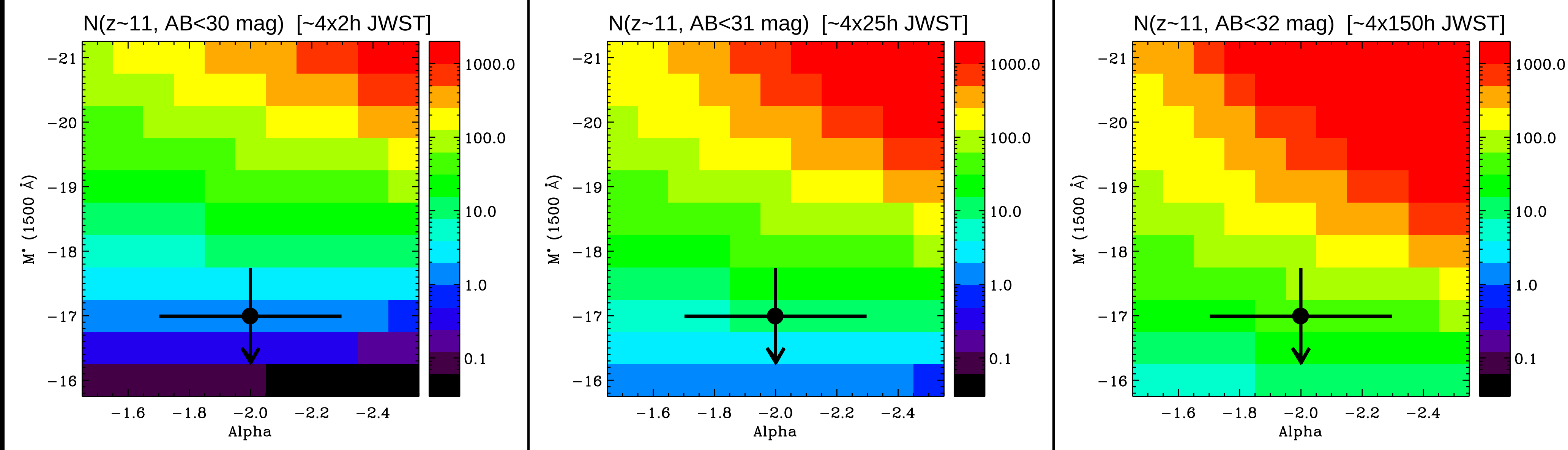
Red and blue lines: 50% 5-σ and 10-σ AB-completeness limits, resp.

THE ASTROPHYSICAL JOURNAL, 752:113 (18pp), 2012 June 20
HELGASON, RICOTTI, & KASHLINSKY



LEFT: Rest-frame UV-LF behavior quite different from longer wavelengths:

Rest-frame UV-LF ($\lesssim$Balmer break) is what NIRCam will observe at z$\gtrsim$10!



What do the 6 possible z$\simeq$9 and single z$\gtrsim$10 HUDF candidate mean?

Integrate Schechter LFs with α(z), Φ^* (z) and M^* (z): $\lesssim$45% sky-coverage by AB$\lesssim$30 objects (Koekemoer+13). Cosmic Variance $\gtrsim$30%.

For any α(z$\gtrsim$9–10), implies M^* (z$\gtrsim$10)$\gtrsim$–17.5 mag (fainter!), so plan:

- (1) [Left] Webb "Medium-Deep" Fields (**WMDF**) (10×4×2h RAW): Expect few z$\simeq$10–12 objects to AB$\lesssim$30 mag, so plan lensing targets.

- (2) [Middle] Webb Deep Field (**WDF**) (4×25h 7-filt NIRCam GTO): Expect 8–25 objects at z$\simeq$10–12 to AB$\lesssim$31 mag.

- (3) [Right] Webb UltraDeep Field (**WUDF**) (4×150h; NIRCam DD?]: Expect 30–90 objects to AB$\lesssim$32 mag, many more if lensing targets.

B, I, J AB-mag vs. half-light radii r_e from RC3 to HUDF limit are shown.

All surveys limited by by SB (+5 mag dash)

Deep surveys bounded also by object density.

Violet lines are gxy counts converted to to natural conf limits.

Natural confusion sets in for faintest surveys (AB$\gtrsim$25). Will update for JWST.